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Student name

CHEMISTRY

Unit 2

Trial Examination

QUESTION AND ANSWER BOOK

Total writing time: 1 hour 30 minutes

Structure of book

Section	Number of questions	Number of marks
A	20	20
B	7	65
	Total	**85**

- Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners, rulers, one scientific calculator.
- Students are NOT permitted to bring into the examination room: blank sheets of paper and/or white out liquid/tape, mobile phones and/or any other unauthorised electronic devices.

Materials supplied

- Question and answer book of 12 pages, with a detachable data sheet in the centrefold and a detachable answer sheet for multiple-choice questions inside the front cover.

Instructions

- Detach the data sheet from the centre of this book and the answer sheet for multiple-choice questions during reading time.
- Write your **name** in the space provided above on this page and on the answer sheet for multiple-choice questions.
- All written responses should be in English.

At the end of the examination

- Place the answer sheet for multiple-choice questions inside the front cover of this book.

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SECTION A – Multiple-choice questions

Instructions for Section A

Answer all questions in pencil on the answer sheet provided for multiple-choice questions.
Choose the response that is **correct** or that **best answers** the question.
A correct answer scores 1, an incorrect answer scores 0.
Marks will **not** be deducted for incorrect answers.
No mark will be given if more than one answer is completed for any question.

Question 1

Water expands on freezing because ice has

A. a more ordered arrangement of molecules

B. a less ordered arrangement of molecules

C. hydrogen bonding between water molecules

D. a high latent heat of fusion

Question 2

If the heat capacity of water is 4.18 J $°C^{-1}$ g^{-1}, then the energy, in kJ, required to raise the temperature of 1.0 kg of water from 20 °C to 40 °C would be

A. 41.8

B. 83.6

C. 4.18×10^4

D. 8.36×10^4

Question 3

Sodium chloride dissolves in water because

A. molecules of NaCl can ionise in water

B. hydrogen bonds can form between ions and molecules

C. of the strong covalent bonds within molecules

D. of ion-dipole atractions

Question 4

An acid is best defined as a substance that

A. reacts with a metal to produce a salt and hydrogen gas.

B. accepts electrons during a chemical reaction.

C. causes moist litmus to change in colour from red to blue.

D. donates protons during a chemical reaction.

Question 5

The Haber process was developed as a wartime alternative to produce ammonia. The reaction to produce ammonia can be written as

$$N_2(g) + 3H_2(g) \rightarrow 2\,NH_3(g)$$

The mass of ammonia, in tonnes, that could theoretically be produced from 2.0 tonnes of hydrogen gas in an excess of nitrogen gas is closest to

A. 2.0

B. 11.4

C. 17.1

D. 22.8

Question 6

The amount of ions, in mol, in 100 ml of a 0.010 M solution of $Al_2(SO_4)_3$ is

A. 0.001

B. 0.002

C. 0.005

D. 0.009

Question 7

The substance anhydrous sodium carbonate, Na_2CO_3, is a very useful substance in an analytical chemistry laboratory. The mass, in gram, of sodium carbonate needed to make 500 mL of a 0.050 M aqueous solution would be

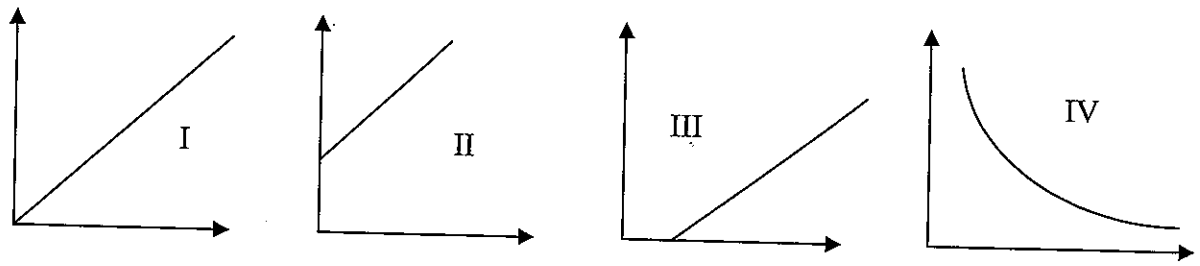
A. 0.265

B. 0.530

C. 1.06

D. 2.65

The next two questions relate to the following graphs.



Question 8

Which graph best represents the way the volume of a sample of an **ideal** gas depends on temperature **in** °C at constant pressure?

A. I

B. II

C. III

D. IV

Question 9

Which graph best represents the way the pressure of an **ideal** gas depends on volume (at constant temperature)?

A. I

B. II

C. III

D. IV

Question 10

If a person accidentally swallows a 0.025 mL drop of liquid nitrogen (density = 0.807 g mL^{-1}), the volume, in mL, of N_2 gas that would be evolved in their body at 100 kPa and 37 °C is closest to?

A. 0.018

B. 0.025

C. 19

D. 37

Question 11

Which of the following will **not** produce carbon dioxide?

A. the action of carbonic acid, H_2CO_3 on magnesium

B. respiration

C. the action of hydrochloric acid on marble chips

D. thermal decomposition of calcium carbonate

Question 12

Which of the following is **not** a greenhouse gas?

A. chlorofluoromethane

B. water vapour

C. nitrogen gas

D. methane

Question 13

A sample of argon occupies 10 L at 2.0 atm and 27 °C. If the same sample of argon is transferred to a 5.0 L container at 1.0 atmosphere, the temperature of the gas would be

A. 75 K

B. 246 K

C. 27 °C

D. 75 °C

Question 14

The Contact process for the synthesis of sulfuric acid involves several stages. A key reaction is the conversion of sulfur dioxide to sulfur trioxide according to the equation:

$$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$$

The maximum volume of sulfur trioxide, in litres, that can be prepared from 100 L of SO_2 and 100 L of O_2, **if all gases are measured at the same temperature and pressure**, is

A. 50

B. 100

C. 150

D. 200

Question 15

In the reaction represented by the equation

$$4HCl(aq) + MnO_2(s) \rightarrow Cl_2(g) + MnCl_2(aq) + 2H_2O(l)$$

A. HCl is the oxidant.

B. Cl_2 is the product of the reduction process.

C. MnO_2 undergoes reduction.

D. $MnCl_2$ is the product of the oxidation process.

Question 16

Which of the following equations is a redox reaction?

A. $Pb^{2+}(aq) + H_2S(aq) \rightarrow PbS(s) + 2H^+(aq)$

B. $I_2(s) + 2OH^-(aq) \rightarrow I^-(aq) + OI^-(aq) + H_2O$

C. $SO_2(g) + 2H_2O(l) \rightarrow HSO_3^-(aq) + H_3O^+(aq)$

D. $PO_4^{3-}(aq) + H_2O(l) \rightarrow HPO_4^{2-}(aq) + OH^-(aq)$

Question 17

The sample of gas that would occupy the largest volume at SLC is

A. 16 g CH_4

B. 32 g O_2

C. 44 g CO_2

D. none of the above as all of the gases would occupy 24.5 L

Question 18

Which of the following is **not** true of ozone?

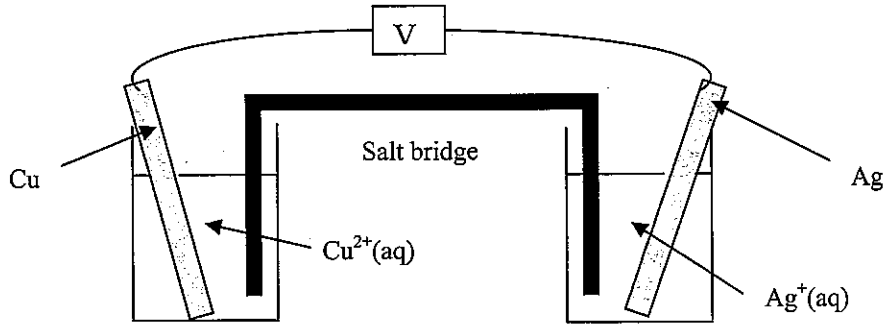
A. It is a liquid at 298 K.

B. It absorbs UV light.

C. It is found at ground level in photochemical smog.

D. It can be generated by electrical discharge through oxygen.

The next two questions refer to the galvanic cell shown below.



Question 19

In the galvanic cell, electrons will flow from the

A. Cu electrode, through the salt bridge, to the Ag electrode.

B. Ag electrode, through the salt bridge, to the Cu electrode.

C. Cu electrode to the Ag electrode in the external circuit.

D. Ag electrode to the Cu electrode in the external circuit.

Question 20

If the salt bridge was soaked in a saturated solution of KNO_3, then as the cell produces energy

A. K^+ ions will migrate towards the half-cell containing the Cu electrode.

B. K^+ ions will migrate towards the half-cell containing the Ag electrode.

C. NO_3^- ions will migrate towards the half-cell containing the Ag electrode.

D. Cu^{2+} ions will migrate towards the half-cell containing the Cu electrode.

END OF SECTION A

SECTION B – Short answer questions

Instructions for Section B

Answer **all** questions in the spaces provided.

To obtain full marks for your responses you should

- give simplified answers with an appropriate number of significant figures for all numerical questions; unsimplified answers will not be given full marks.
- show all working in your answers to numerical questions. No credit will be given for an incorrect answer unless it is accompanied by details of the working.
- make sure chemical equations are balanced and that the formulas for individual substances include an indication of state; for example, $H_2(g)$; NaCl(s)

Question 1

When potassium nitrate is heated, it decomposes according to the equation

$$2\ KNO_3(s) \rightarrow 2\ KNO_2(s) + O_2(g)$$

a. If 2.50 g of solid potassium nitrate was heated, what mass of oxygen gas might have been expected to form?

4 marks

b. In fact, only 0.290 g of oxygen was actually produced. Calculate the mass of

i. KNO_2 produced

ii. KNO_3 which did not react

4 + 3 = 7 marks

Total 11 marks

Question 2

Some students carried out a titration to determine the concentration of a hydrochloric acid solution. Their results indicated that an average titre of 17.0 mL of the acid solution was required to neutralise 20.00 mL of a 0.050 M Na_2CO_3 solution in a conical flask.

a. Write a balanced equation, including states, for the reaction.

_____

2 marks

b. Determine the concentration of the hydrochloric acid solution.

_____

_____

_____

3 marks

c. The student's instructions made reference to titrating until concordant titres were achieved. What is meant by the term 'titre'?

_____

_____

1 mark

d. Write down three possible titres that would indicate that the student had achieved this.

_____

1 mark

Total 7 marks

Question 3

There has been recent concern in Australia over the use of coal to produce electricity.
List the **formula** of three atmospheric pollutants which could be produced from the combustion of coal containing some sulfur. Support your choices with a balanced chemical equation where possible.

_____

_____

_____

6 marks

Question 4

Write balanced equations, including states, for each of the following:

a. photosynthesis

_____

b. aqueous solutions of sulfuric acid and barium hydroxide, $Ba(OH)_2$ solutions are mixed

_____

c. the combustion of pentane vapour, C_5H_{12} in excess oxygen

_____

d. the dissolving of copper (II) nitrate in water

_____

e. production of ozone by electrical discharge through air.

_____

f. carbon dioxide and limewater (solution of calcium hydroxide)

_____

g. the oxidation of aqueous iodine, I_2, to iodate ions, IO_3^-, in acidic solution.

_____

$2 \times 7 \div 2 = 16$ marks

Question 5

a. Carbonic acid, H_2CO_3 is referred to as a weak, diprotic acid. It is formed when carbon dioxide dissolves in water.

i. Explain why carbonic acid is regarded as a weak acid.

_____

_____

ii. Write two balanced equations which show that carbonic acid is a weak diprotic acid in water.

_____

_____

iii. A pressurized bottle holds 500 mL of an aqueous solution containing 2.20 g of CO_2. The bottle is heated to 40 °C and then opened to the atmosphere so that all the CO_2 in the solution escapes as CO_2 gas . Calculate, in litres, the volume of CO_2 that would be evolved at 1.00 atm pressure and 40 °C.

_____

_____

_____

_____

1 + 2 + 4 = 7 marks

b. Write the symbols for each of the following

i. the conjugate acid of OH^- _____

ii. the conjugate base of HS^- _____

1 + 1 = 2 marks

c. Calculate the pH of 0.0005 M NaOH (aq).

_____

_____

_____

2 marks

Total 11 marks

Question 6

When aqueous solutions of sodium hydroxide (NaOH) and iron(III) chloride ($FeCl_3$) react, a red-brown precipitate of iron(III) hydroxide is formed. The overall equation for the reaction is:

$$FeCl_3\,(aq) + 3\,NaOH(aq) \rightarrow Fe(OH)_3(s) + 3\,NaCl\,(aq)$$

a. Write a balanced **ionic** equation for the formation of the precipitate.

_____

1 mark

b. If 18.0 mL of 1.0 M NaOH(aq) is added to 20 mL of 1.0 M $FeCl_3$(aq),

i. Which substance is in excess and by how many mol?

_____

_____

_____

_____

_____

ii. What mass of iron (III) hydroxide would be precipitated?

_____

_____

_____

5 + 2 = 7 marks

Total 8 marks

Question 7

Wet corrosion is described as a galvanic process.

a. Apart from iron, what two substances are required for wet corrosion to occur?

_____

1 mark

b. Write two half equations to represent the initial stage of wet corrosion on the surface of a nail. Next to each half equation indicate the polarity of each.

_____

_____

_____

3 marks

c. What causes different sites on a nail to act as anodic or cathodic regions?

_____

_____

1 mark

d. Why does the addition of salt accelerate corrosion?

_____

_____

1 mark

Total 6 marks

END OF EXAMINATION

SECTION A (Total 20 marks)

1.	A	**2.**	B	**3.**	D	**4.**	D	**5.**	B
6.	C	**7.**	D	**8.**	B	**9.**	D	**10.**	C
11.	A	**12.**	C	**13.**	A	**14.**	B	**15.**	C
16.	B	**17.**	D	**18.**	A	**19.**	C	**20.**	B

Comments for Section A answers

Question 1
Ice has a highly ordered structure compared with liquid water and this requires slightly less nearest neighbours. As ice melts, the density of water rapidly increases by about 10%.
(Answer **A**)

Question 2
$E = mc\Delta T = 4.18 \times 1000 \times 20 = 8.36 \times 10^4$ J = 83.6 kJ (Answer **B**)

Question 3
Sodium chloride is made up of ions. The negative ends of the water dipoles attract the sodium ions and the positive ends of the water dipoles attract the chloride ions. The interactions are between ions and dipoles. (Answer **D**)

Question 4
Acids are proton donors (Answer **D**)

Question 5
$n(H_2) = 2.0 \times 10^6 / 2 = 1.0 \times 10^6$ mol $n(NH_3) = 2/3\ n(H_2) = 2/3 \times 1.0 \times 10^6 = 0.67 \times 10^6$

$m(NH_3) = n \times M = 0.67 \times 10^6 \times 17.0 = 11.4 \times 10^6 = 11.4$ tonnes (Answer **B**)

Question 6
n $Al_2(SO_4)_3 = c \times V = 0.010 \times 100 \times 10^{-3} = 0.00100$ mol **and** 5 ions per cluster
n(ions) = 0.00500 mol (Answer **C**)

Question 7
$n(Na_2CO_3) = c \times V = 0.050 \times 0.500 = 0.0250$ mol
$m(Na_2CO_3) = n \times M = 0.0250 \times 106 = 2.65$ g (Answer **D**)

Question 8
The graph must be a straight line but must have a positive intercept (Answer **B**)

Question 9
$PV = nRT$ so $P \propto 1/V$ (Answer **D**)

Question 10
$PV = nRT$ $V = nRT/P = mRT/MP$ and $d = m/v$ so $m = d \times v$

$V = d \times v \times R \times T / M \times P$

$V = 0.025 \times 0.807 \times 8.31 \times 310 / (28 \times 100) = 1.9 \times 10^{-2}$ L = 19 mL (Answer **C**)

Question 11
Carbonic acid on magnesium will produce hydrogen gas. (Answer **A**)

Question 12
Greenhouse gases include carbon dioxide, methane, water vapour, chlorofluorocarbons and oxides of nitrogen. Nitrogen gas itself is not a greenhouse gas. (Answer **C**)

Question 13
$PV = nRT$ n = constant

$P_1V_1 / T_1 = P_2V_2 / T_2$

$T_2 = P_2V_2T_1 / P_1V_1 = 1.0 \times 5.0 \times 300 / (2.0 \times 10) = 75$ K (Answer **A**)

Question 14
At constant T and P, V is directly proportional to n

2 vol SO_2 combine with 1 vol O_2 to give 2 vol of SO_3

100 L of SO_2 require only 50 L of O_2 to produce 100 L of SO_3 (Answer **B**)

Question 15
The oxidation number of manganese goes from +4 to +2 so MnO_2 undergoes reduction. (Answer **C**)

Question 16
I_2 $I = 0$ goes to I^- where $I = -1$ and OI^- here $I = +1$ (Answer **B**)

Question 17
$n(CH_4) = m/M = 16/16 = 1.0$ $V = n \times V_m = 1.0 \times 24.5 = 24.5$ L

$n(O_2) = m/M = 32/32 = 1.0$ $V = n \times V_m = 1.0 \times 24.5 = 24.5$ L

$n(CO_2) = m/M = 44/44 = 1.0$ $V = n \times V_m = 1.0 \times 24.5 = 24.5$ L

All of the volumes are the same at SLC. (Answer **D**)

Question 18
Ozone is a gas at RT. It has to be cooled to -111 °C to become a liquid. (Answer **A**)

Question 19
$Ag^+ + e \rightarrow Ag$ + 0.80 V
$Cu^{2+} + 2e \rightarrow Cu$ + 0.34 V

Electrons flow from the strongest reductant, Cu, to the strongest oxidant Ag^+ via the external circuit and the silver electrode. (Answer **C**)

Question 20
The positive charge in the Ag^+ / Ag half cell would decrease unless compensated for by the movement of K^+ ions to this half cell. (Answer **B**)

SECTION B

Question 1 (11 marks)

a. $M(KNO_3) = 39.1 + 14.0 + 3 \times 16.0 = 101 \text{ g mol}^{-1}$ **(1 mark)**

$n(KNO_3) = m/M = 2.50 / 101 = 2.48 \times 10^{-2} \text{ mol}$ **(1 mark)**

$n(O_2) = ½\ n(KNO_3) = ½ \times 2.48 \times 10^{-2} = 1.24 \times 10^{-2} \text{ mol}$ **(1 mark)**

$m(O_2) = n \times M = 1.24 \times 10^{-2} \times 32.0 = 0.396 \text{ g}$ **(1 mark)**

b. **i.** $n(O_2) = m / M = 0.290 / 32.0 = 9.06 \times 10^{-3} \text{ mol}$ **(1 mark)**

$n(KNO_2) = 2 \times n(O_2) = 1.82 \times 10^{-2} \text{ mol}$ **(1 mark)**

$M(KNO_2) = 39.1 + 14.0 + 2 \times 16.0 = 85.1 \text{ g mol}^{-1}$ **(1 mark)**

$m(KNO_2) = n \times M = 1.82 \times 10^{-2} \times 85.1 = 1.55 \text{ g}$ **(1 mark)**

ii. $n(KNO_3)_{\text{remaining}} = n(KNO_3)_{\text{initially}} - n(KNO_3)_{\text{reacting}}$
$= 2.48 \times 10^{-2} - 1.82 \times 10^{-2} = 0.66 \times 10^{-2} \text{ mol}$ **(2 marks)**

$m(KNO_3)_{\text{remaining}} = n \times M = 0.66 \times 10^{-2} \times 101 = 0.665 \text{ g}$ **(1 mark)**

Question 2 (7 marks)

a. $Na_2CO_3(aq) + 2HCl(aq) \rightarrow 2\ NaCl(aq) + H_2O(l) + CO_2(g)$
(**1 mark** correct formulae and **1 mark** for a balanced equation)

b. $n(Na_2CO_3) = c \times V = 0.050 \times 20.00 \times 10^{-3} = 1.00 \times 10^{-3} \text{ mol}$ **(1 mark)**

$n(HCl) = 2 \times n(Na_2CO_3) = 2.00 \times 10^{-3} \text{ mol}$ **(1 mark)**

$[HCl] = n / V = 2.00 \times 10^{-3} / (17.0 \times 10^{-3}) = 0.118 \text{ M}$ **(1 mark)**

c. A titre is the accurate volume of solution run out of the burette **(1 mark)**

d. concordant titres are titres within 0.1 mL of each other
eg. 17.0, 17.1, 17.0 or 17.0, 17.0, 17.0 **(1 mark)**

Question 3 (6 marks)

CO_2	**(1 mark)**	$C(s) + O_2(g) \rightarrow CO_2(g)$	**(1 mark)**
CO	**(1 mark)**	$2\ C(s) + O_2(g) \rightarrow 2\ CO(g)$	**(1 mark)**
SO_2	**(1 mark)**	$S(s) + O_2(g) \rightarrow SO_2(g)$	**(1 mark)**

Other possibilities

NO / NO_2 accept NO_x eg. $N_2(g) + O_2(g) \rightarrow 2\ NO(g)$

Particulate matter / sooty carbon (unburnt C)

Question 4 (16 marks)

1 mark for correct formulae, 1 mark for correct balance, plus a total of two marks for including states consistently.

a. $6\ CO_2\ (g) + 6\ H_2O(l) \rightarrow C_6H_{12}O_6\ (aq) + 6\ O_2(g)$ **(1 mark + 1 mark)**

b. $H_2SO_4\ (aq) + Ba(OH)_2(aq) \rightarrow 2\ H_2O\ (l) + BaSO_4(s)$ **(1 mark + 1 mark)**

c. $C_5H_{12}\ (g) + 8\ O_2\ (g) \rightarrow 5\ CO_2\ (g) + 6\ H_2O\ (g)$ **(1 mark + 1 mark)**

d. $Cu(NO_3)_2\ (s) \rightarrow Cu^{2+}(aq) + 2\ NO_3^-\ (aq)$ **(1 mark + 1 mark)**

e. $3\ O_2\ (g) \rightarrow 2\ O_3\ (g)$ **(1 mark + 1 mark)**

f. $CO_2\ (g) + Ca(OH)_2\ (aq) \rightarrow CaCO_3\ (s) + H_2O\ (l)$ **(1 mark + 1 mark)**

g. $I_2\ (aq) + 6\ H_2O\ (l) \rightarrow 2\ IO_3^-(aq) + 12\ H^+(aq) + 10\ e$ **(1 mark + 1 mark)**

(plus 2 marks for states)

Question 5 (11 marks)

a. i. Carbonic acid molecules only undergo a relatively small percentage of ionisation to produce H^+ ions. **(1 mark)**

ii. $H_2CO_3(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HCO_3^-(aq)$ **(1 mark)**

$HCO_3^-(aq) + H_2O\ (l) \rightleftharpoons H_3O^+\ (aq) + CO_3^{2-}(aq)$ **(1 mark)**

iii. $n(CO_2) = m / M = 2.20 / 44.0 = 0.0500$ mol **(1 mark)**

$PV = nRT$, therefore $V = nRT / P$ **(1 mark)**

$V = 0.0500 \times 8.31 \times 313 / 101.3 = 1.28$ L

(1 mark correct values substituted + 1 mark correct calculation)

b. i. H_2O **(1 mark)**

ii. S^{2-} **(1 mark)**

c. $pOH = -\log_{10}[OH^-] = -\log_{10} 0.0005 = 3.3$ therefore $pH = 10.7$ **(2 marks)**

Question 6 (8 marks)

a. $Fe^{3+}(aq) + 3\ OH^-(aq) \rightarrow Fe(OH)_3\ (s)$ **(1 mark)**

b. **i.** $n(NaOH) = c \times V = 1.0 \times 18.0 \times 10^{-3} = 0.018$ mol $= n(OH^-)$ **(1 mark)**

$n(FeCl_3) = c \times V = 1.0 \times 20.0 \times 10^{-3} = 0.020$ mol $= n(Fe^{3+})$ **(1 mark)**

$n(OH^-) / n(Fe^{3+}) = 3 / 1$ **(1 mark)**

All the OH^- reacts but only need 0.006 mol Fe^{3+}

Therefore $FeCl_3$ is in excess **(1 mark)** by 0.014 mol **(1 mark)**

ii. $n(Fe^{3+})_{reacting} = nFe(OH)_3$ **(1 mark)**

$m\ Fe(OH)_3 = n \times M = 0.006 \times 106.9 = 0.64$ g **(1 mark)**

Question 7 (6 marks)

a. oxygen (air) and water **(1 mark)**

b. (-) $Fe\ (s) \rightarrow Fe^{2+}\ (aq) + 2e$ **(1 mark)**
(+) $O_2\ (aq) + 2\ H_2O\ (l) + 4\ e \rightarrow 4\ OH^-\ (aq)$ **(1 mark)**

plus 1 mark for polarities as indicated.

c. Differences in oxygen concentration **(1 mark)**. Oxygen concentration is lower beneath a water droplet than beside a water droplet.

d. Salt contains ions which improves conductivity in solution **(1 mark)** and therefore decreases resistance to electron flow between anodic and cathodic regions.

END OF SUGGESTED SOLUTIONS